Ultrastructure of Myodocopid Shells (Ostracoda)

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Abstract

Based on the study of scanning electron micrographs of cross-sections of ostracod shells representing 17 species in genera of the suborders Cladocopina, Halocypridina, and Myodocopina, five primary components are identified in the endocuticle: 1—laminate, 2—columnar, 3—fine granular, 4—coarse granular, 5—homogeneous. Crystalline nodules, rare *in vivo*, but common in preserved specimens, are considered to represent a secondary component. Preliminary experimentation with sun-dried shells of *Vargula hilgendorfii* indicates that crystalline nodules form in 10% buffered formalin, a commonly used preservative of plankton. Examination of two growth stages of this species suggests the same general combination of components during ontogeny.

Pelagic species of *Gigantocypris*, *Halocypris*, *Conchoecia*, and *Macrocypridina* have laminate endocuticles, but the pelagic *Codonocera polygonia* has both laminate and coarse granular components in the endocuticle. Benthonic species may have only one or a combination of any of the five components, but not more than four components in a species.

Based on this and previous studies, the ultrastructures of the endocuticles of the following taxa are known: *Metapolycope hartmanni*, *Polycope* sp., *Conchoecia atlantica*, *C. valdiviae*, *C. belgica*, *Halocypris inflata*, *Thaumatoconcha caraionae*, *T. tuberculata*, *Asteropterygion setiferum*, *Macrocypridina castanea*, *Gigantocypris muelleri*, *Scleroconcha folinii*, *Vargula hilgendorfii*, *Codonocera polygonia*, *Eusarsiella texana*, *E. disparalis*, *Spinacopia* sp.

Introduction

The purpose of this study is to examine cross-sections of the shells of myodocopid ostracods with scanning electron microscopy (SEM) in order to determine their ultrastructure. We report on the ultrastructure of 17 species in the suborders Cladocopina, Halocypridina, and Myodocopina, and we identify five different primary components in the shells (Table 1); crystalline nodules are considered to be a secondary component. The combinations of the various components of the shells are discussed relative to taxonomy and environment.

Methods

Scanning electron microscopy techniques in the National Museum of Natural History were re-

TABLE 1—SHELL ULTRASTRUCTURE AND HABITAT OF MYODOCOPA

Taxon	Laminate	Columnar	Fine granular	Coarse granular	Homogeneous	Habitat	Source
Suborder CLADOCOPINA							
Metapolycope hartmanni Kornicker and van Morkhoven, 1976	—	X	X	—	—	B	Kornicker and van Morkhoven, 1976 fig. 7d.
Polycope sp.	—	X	X	—	—	B	Herein, Pl. 2, fig. 4.
Suborder HALOCYPRIDINA							
Conchoecia atlantica (Lubbock, 1856)	X	—	—	—	—	P	Herein, Pl. 1, figs. 6–9; Pl. 2, fig. 5.
C. belgica Müller, 1906b	X	—	—	—	—	P	Bate and East, 1972, fig. 10; 1975, Pl. 3, fig. 8.
C. valdiviae Müller, 1906a	X	—	—	—	—	P	Bate and Sheppard, 1982, Pl. 7, figs. 1, 2.
Halocypris inflata (Dana, 1849)	X	—	—	—	—	P	Bate and Sheppard, 1982, Pl. 4, fig. 4; Pls. 5–10.
Thaumatoconcha caraionae (Kornicker and Sohn, 1976)	—	X	—	—	—	B	Herein, Pl. 4, fig. 7.
T. tuberculata Kornicker and Sohn, 1976	—	X	X	—	—	B	Herein, Pl. 4, figs. 8–10.
Suborder MYODOCOPINA							
Asteropterygion setiferum Kornicker and Caraion, 1974	X	—	—	—	—	B	Herein, Pl. 1, figs. 10, 11; Kornicker, 1975, figs. 17, 18.
Codonocera polygonia Poulsen, 1962	X	—	—	X	—	P	Bate and Sheppard, 1982, Pl. 2, fig. 5.
Eusarsiella disparalis (Darby, 1965)	X	—	X	X	—	B	Herein, Pl. 4, figs. 3–6; Pl. 5, figs. 14, 15.
E. texana (Kornicker and Wise, 1962)	—	—	—	X	—	B	Herein, Pl. 5, figs. 7–9.
Gigantocypris muelleri Skogsberg, 1920	X	—	—	—	—	P	Herein, Pl. 1, figs. 1–5; Harding, 1965, fig. 8.
Macrocypridina castanea (Brady, 1897)	X	—	—	—	—	P	Herein, Pl. 2, fig. 1; Bate and East, 1975, Pl. 3, figs. 9, 10.
Scleroconcha folinii (Brady, 1871)	—	X	—	—	X	B	Herein, Pl. 2, figs. 2, 3.
Spinacopia sp.	X	—	X	—	—	B	Herein, Pl. 5, figs. 10–13.
Vargula hilgendorfii (Müller, 1890)	X	X?	—	X	X	B	Herein, Pl. 2, figs. 6–8; Pl. 3, figs. 1–7; Pl. 4, figs. 1, 2.

(X = present, — = absent, B = benthonic, P = pelagic)

cently described (Sohn, 1983, p. 10). Except for those specimens of *Vargula hilgendorfii* (Müller, 1890) that were sun-dried as soon as collected, the specimens prepared for scanning electron microscopy had been preserved in alcohol. The sun-dried specimens were fractured by pressing with a thick needle, and the fragments were mounted on stubs for study. The wet specimens were either

PLATE 1—Figs. 1–5. *Gigantocypris muelleri* Skogsberg, 1920. USNM 151241A. 1, 2, section made by cryofracture to show laminae, approx. × 1,450 and × 5,800, respectively. Area of 2 shown by arrow on fig. 1. Figs. 3–5, torn sections of the same specimen, approx. × 470, × 1,500, and × 4,700, respectively. Arrow on fig. 3 indicates epicuticle; area of 5 shown on fig. 4 by arrow; outer surface of valve towards bottom of plate. Locality 1. Figs. 6–9. *Conchoecia atlantica* (Lubbock, 1856). Adult male, left valve, USNM 149290. 6, 7, cut sections near dorsal margin above incisur of valve showing laminae, approx. × 2,000 and × 4,500, respectively. Adhering objects are bacterial contamination during preparation. Sections oriented with outer surface of valve towards top of plate. 8, 9, cut section in other area behind midlength at midheight of same fragment, approx. × 2,200 and × 4,500, respectively. Area of 9 shown by arrow on fig. 8; laminae separated during preparation. Sections oriented with outer surface of valve towards top of plate. Locality 2. Figs. 10, 11. *Asteropterygion setiferum* (Kornicker and Caraion, 1974). Adult female, right valve sliced with razor blade, USNM 143996. 10, epicuticle (arrow) and part of laminated endocuticle, showing that elongate process is confined to epicuticle, approx. × 5,100. 11, detail showing laminae, approx. × 9,800. Sections oriented with outer surface of valve towards top of plate. Locality 3.
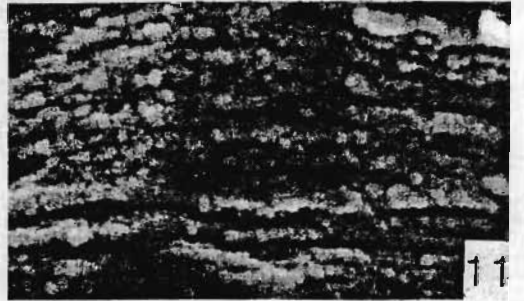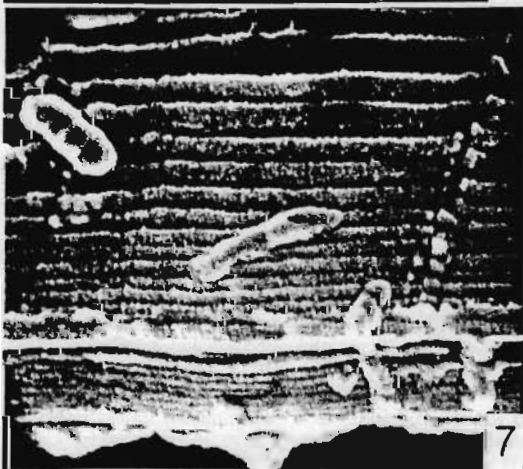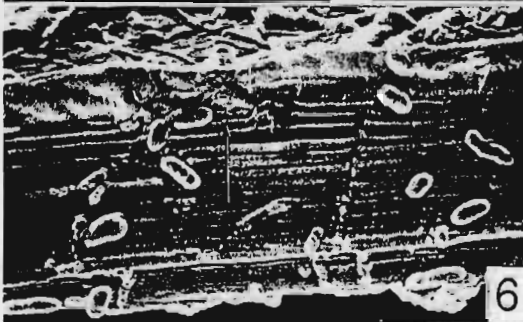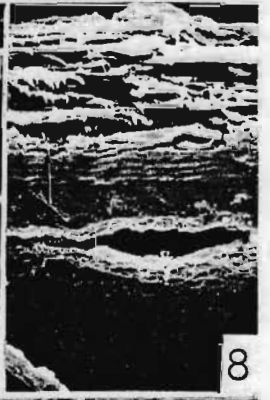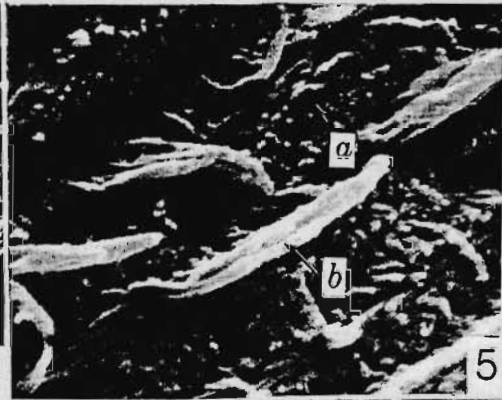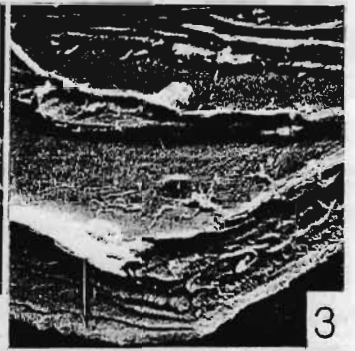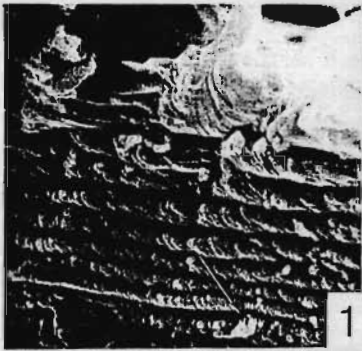
cryofractured or cut with a sharp blade and then freeze-dried. When a carapace of a myodocopid is cut, the edges of the specimens may smear, masking the ultrastructure (lower part of Pl. 1, fig. 9); cryofracture more consistently gives better results. The technique of cryofracture consists of quick-freezing a specimen immersed in a drop of water at −40°C; the frozen drop is then fractured by hitting with a sharp edge.

The specimen illustrating the dorsal attachment of the two valves (ligament) on Pl. 3, fig. 7, is a sun-dried carapace of *V. hilgendorfii*. Before freeze-drying, the carapace was decalcified by soaking in a slightly acid wetting agent (Aerosol OT), and some of the organic matter was removed with dilute sodium hypochlorite.

DISCUSSION

We follow Kornicker (1969, p. 114) as well as Bate and Sheppard (1982, p. 29) in considering the shell of Myodocopa to consist of two parts: an epicuticle and an endocuticle (=procuticle). The epicuticle consists of a very thin layer above the outer surface of the thicker and more structurally complex endocuticle. The epicuticle appears to lack internally differentiated ultrastructures. Puncta as well as certain surface structures on the valves are confined to the epicuticle in the taxa examined. The mineralogy of myodocopid shells is poorly known. E. R. Roseboom (in Sohn and Kornicker 1969, p. 103) determined that the shell of *V. hilgendorfii* contains monohydrocalcite ($CaCO_3 \cdot H_2O$). Crystalline nodules in the myodocopids are calcite (Sohn and Kornicker, 1969; Bate and Sheppard, 1982, p. 27).

The appearance of the ultrastructure may depend on the method of fracturing of the shell. Plate 1, figures 1 and 2, are of a cut cross-section normal to the valve surface of *Gigantocypris muelleri* Skogsberg, 1920, whereas Pl. 1, figs. 3–5, are of an oblique tear on the same specimen showing laminae in three dimensions. Similar influences of preparation are illustrated for *Conchoecia atlantica* (Lubbock, 1856) of which Pl. 1, figs. 6 and 7 are of clean cuts, whereas figures 8 and 9 illustrate frayed edges of some of the laminae.

We recognize five primary components in the ultrastructure of myodocopid shells (Table 1): 1, laminate; 2, columnar; 3, fine granular; 4, coarse granular, and 5, homogeneous.

1. Laminate: This component consists of thin layers in cut sections; on torn sections, however, the layers have ragged edges "chitin" shown on Pl. 1, figs. 3–5. In *Gigantocypris muelleri*, finely granulated layers separate the "chitin" layers.

2. Columnar: This component consists of lineations perpendicular to the shell surfaces (Pl. 2, figs. 3, 4)

3. Fine granular: This component consists of unlayered small rounded granules (Pl. 2, fig. 4).

4. Coarse granular: This component consists of relatively large polygonal grains with con-

PLATE 2—Fig. 1. *Macrocypridina castanea* (Brady, 1897). Adult male, USNM 151167B, cross-section of carapace, approx. ×2,500. Locality 4. Figs. 2, 3, *Scleroconcha folinii* (Brady, 1871). Ovigerous female, USNM 141545, cut sections near central adductor muscles, approx. ×510 and ×4,900, respectively. Area of fig. 3 shown on fig. 2 by arrow. Note on fig. 2 thin epicuticle, which separated from endocuticle during preparation. Locality 5. Fig. 4, *Polycope* sp. Adult male, USNM 149325, broken section, approx. ×2,700. Note relatively thick epicuticle and shallow puncta confined to epicuticle (arrow). Locality 6. Fig. 5. *Conchoecia atlantica* (Lubbock, 1856). Adult male, left valve. USNM 149290. Broken section at inner fold of rostrum showing laminae of endocuticle and bacteria contamination on epicuticle, approx. ×2,200. Same specimen as Pl. 1, figs. 6–9. Locality 2. Figs. 6–8. *Vargula hilgendorfii* (Müller, 1890). Sun-dried carapace, crushed fragments, USNM 193163C. 6, broken section of right valve, approx. ×4,850, showing coarse granular, laminate, and columnar(?) components of endocuticle. 7, section of fragment showing in two dimensions the coarse granular middle component (arrow *a*), and the innermost layer (arrow *b*), approx. ×1,950. 8, montage of cross-section, approx. ×4,850, showing epicuticle (arrow *a*), four components of endocuticle (arrows *b–e*). Locality 7.
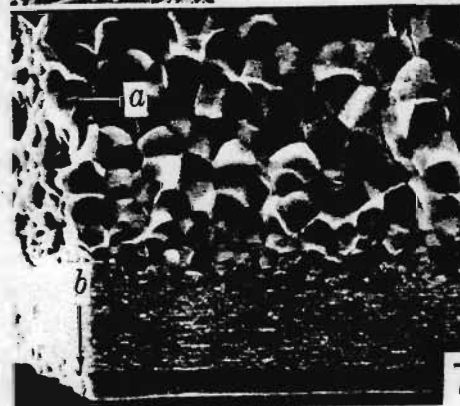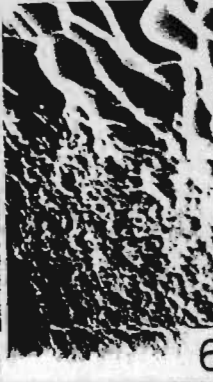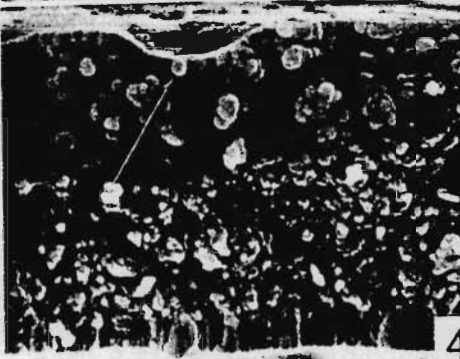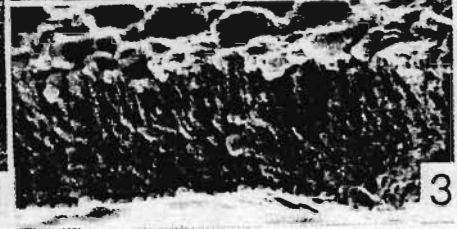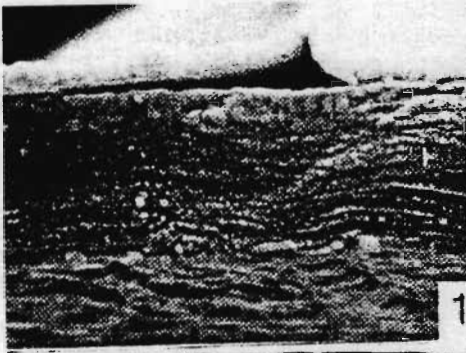
choidal faces convex towards the outside of the valve (Pl. 2, figs. 7, 8). We think that the granules in this component (Pl. 4, figs. 3–6) and the net-like counterparts (Pl. 4, figs. 1, 2; Pl. 5, figs. 11, 12, 14, 15) are *post-mortem* artifacts resulting from dehydration of the monohydrocalcite-protein complex in the particular kind of nonlaminate ultrastructure forming the endocuticle.

5. **Homogeneous:** This component is dense and non-granular under magnifications examined (Pl. 2, fig. 8b).

In addition to the primary components, we recognize crystalline nodules as a secondary component. These calcite nodules are sparse *in vivo*, are common as a posthumous component in preserved specimens and can be produced in the laboratory (Pl. 3, fig. 6; Pl. 4, figs. 8, 9; Pl. 5, figs. 1–7, 9–13; Pl. 6).

OBSERVATIONS

The components are distributed among the taxa as follows:

Endocuticle with only laminate component: Taxa with laminate endocuticles are listed on Table 1, and this structure is illustrated on Pl. 1, figs. 10, 11 for *Asteropterygion setiferum*. The ultrastructure of the shell consists of a thin epicuticle (arrow on fig. 10) not readily distinguishable from the underlying lamina of the endocuticle. The surface ornaments or processes are extensions of the epicuticle (fig. 10). The endocuticle is uniformly laminated (fig. 11). Additional illustrations of the ultrastructure of this specimen are in Kornicker (1975, Fig. 18). *Macrocypridina castanea* has a similar endocuticle (Pl. 2, fig. 1); see also Kornicker et al. (1976, fig. 2d).

The ultrastructure of *Conchoecia atlantica* is illustrated on Pl. 1, figs. 6–9, and Pl. 2, fig. 5. This species has a thin dense epicuticle (arrow on Pl. 1, fig. 6). In an adult male of this species the laminations of the endocuticle become progressively thinner inward from the outer margin. However, the innermost group of relatively uniformly thinner laminae is separated from the main laminate component by a single thicker lamina (Pl. 1, figs. 6, 7). The endocuticle on the inside fold of the rostrum is also laminate (Pl. 2, fig. 5). Bate and Sheppard (1982, Pl. 7) illustrated a similar progressively thinning laminae in *C. valdiviae*. Bate and East (1972, Fig. 10) showed that a laminate ultrastructure is present in *C. belgica*. *Halocypris inflata* has a similar laminate ultrastructure (Bate and Sheppard, 1982, Pls. 4, 6, 8, 9).

The ultrastructure of *Gigantocypris muelleri* is illustrated on Pl. 1, figs. 1–5. This species has a thin, dense epicuticle (arrow in Pl. 1, fig. 3), and the laminae of the endocuticle become progressively thicker inward from the outer margin (Pl. 1, fig. 1). Figs. 3–5 show a torn cross-section, whereas figs. 1 and 2 illustrate a cross-section obtained by cryofracture. The torn sections demonstrate that the individual lamina is complex. Each lamina consists of both granular (arrow *a* on fig. 5) and fibrous parts (arrow *b* on fig. 5). Similarly laminated ultrastructures in *G. muelleri* were illustrated on additional specimens by Harding (1965, Fig. 8) and by Kornicker et al. (1976, Fig. 15f).

The alternating granular and fibrous layers (Pl. 1, fig. 5) of the laminate component in the slightly calcified pelagic *Gigantocypris muelleri* were not observed in the benthonic more heavily calcified taxa.

Endocuticle without laminate and with columnar, fine granular, or homogeneous components: The ultrastructure of *Scleroconcha folinii* is shown on Pl. 2, figs. 2, 3. The epicuticle is thin and pustulose. The inner part of the endocuticle is homogeneous, the outer part is columnar (fig. 3).

The ultrastructure of *Polycope* sp. is shown on Pl. 2, fig. 4. The epicuticle is thin and punctate (arrow on fig. 4). The endocuticle is finely granular with a thin columnar inner component (fig. 4)
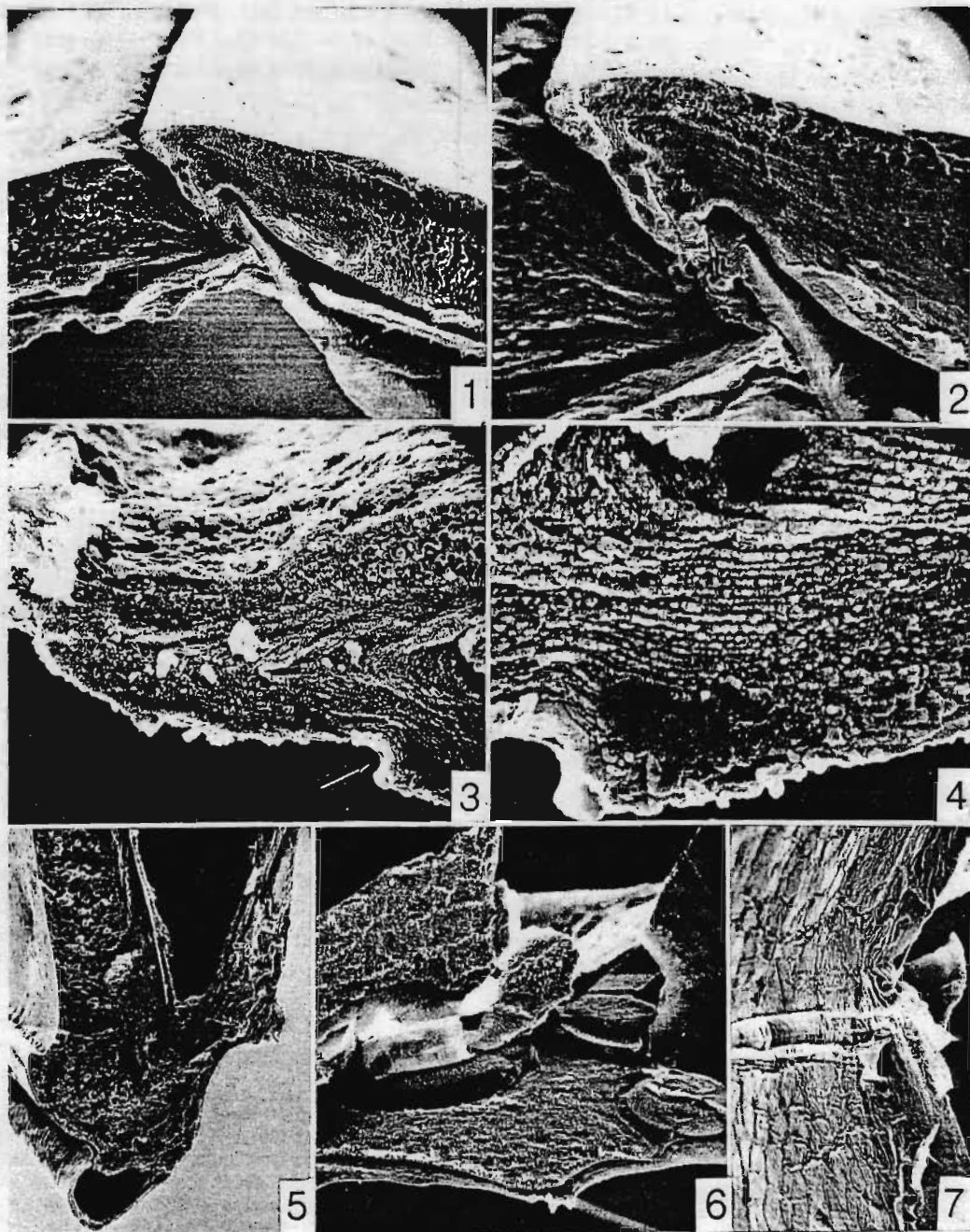
PLATE 3—Figs. 1–7. *Vargula hilgendorfii* (Müller, 1890). 1, 2, 5, sliced cross-section of carapace near midlength. USNM 93001B. Locality 11. 1, 2, cross-section at hinge showing laminated component replacing coarse granular component, approx. ×640 and ×1,267, respectively. 5, cross-section of the same specimen at free margin showing coarse granular and laminate components, approx. ×490. 3, 4, 6, cryofractured carapace that had been preserved in alcohol. USNM 193164. Locality 8. 3, detail of infold demonstrating laminate component folded inward to form infold, approx. ×1,000. 4, laminated infold, area shown by arrow on fig. 3, approx. ×1,850. 6, nodules postulated to have formed *in vivo*, approx. ×120. 7, sun-dried decalcified carapace demonstrating dorsal attachment of the valves (arrow shows ligament), approx. ×210. USNM 193163A. Locality 7.

Two species of *Thaumatoconcha* Kornicker and Sohn, 1976 have a thin epicuticle. The endocuticle of *T. caraionae* is columnar (Pl. 4, fig. 7). *T. tuberculata* has an additional fine grained granular component between the epicuticle and the columnar components (Pl. 4, figs. 8–10). The columnar component of *T. tuberculata* appears to be prismatic, possibly due to recrystallization as suggested by its nodose inner surface (Pl. 4, fig. 8, lower left in fig. 9). This structure might be due to coalescing nodules.

Endocuticle with laminate and coarse granular components, and with or without homogeneous, fine granular, or columnar components: The ultrastructure of *Vargula hilgendorfii* is shown on Pl. 2, figs. 6–8; Pl. 3; Pl. 4, figs. 1, 2; Pl. 5, figs. 1–6; Pl. 6, Pl. 7. The epicuticle is thin and punctate (arrow *a* on Pl. 2, fig. 8). The endocuticle consists of four components: 1, an outer homogeneous layer under the epicuticle (arrow *b* on Pl. 2, fig. 8); 2, a thick coarse granular middle layer in which the grains decrease in size toward the inside (arrow *a* on Pl. 2, fig. 7; arrow *c* on Pl. 2, fig. 8); 3, a laminate layer consisting of many thin laminae (arrow *d* on Pl. 2, fig. 8), and 4, an innermost thin, poorly defined columnar (?) layer (Pl. 2, bottom fig. 6, *b*, fig. 7, *e*, fig. 8). This innermost layer may represent the basement membrane shown in *Halocypris inflata* by Bate and Sheppard (1982, Pl. 6), but in this study it is provisionally considered part of the endocuticle.

Eusarsiella disparalis differs from *V. hillgendorfii* in that the component between the epicuticle and the coarse granular component is fine granular instead of homogeneous (Pl. 4, figs. 3, 4), and in the absence of the innermost columnar component (Pl. 4, figs. 5, 6). The coarse granular component is present in *E. texana* (Pl. 5, figs. 7, 8); however, the other components are indistinct due to the formation of crystalline nodules. The similarly recrystallized specimen of *Spinacopia* sp. (Pl. 5, figs. 10–13) has a coarse granular component above a laminate inner component.

Endocuticles with crystalline nodular component: Calcareous nodules are common components of myodocopid shells, but their distribution is variable (abundant in some carapaces, absent in others); and the distribution in one valve may differ considerably from that in the opposite valve of the same specimen. Although nodules have not yet been recorded in ostracods other than myodocopids, they are present in other Crustacea (Sohn and Kornicker, 1969; Neville, 1975, p. 316 and references therein). Because *post-mortem* nodules may form rapidly, it is difficult to identify nodules that may have formed *in vivo*. Myodocopid shells without nodules rapidly develop nodules when soaked in water, but not when soaked or preserved in alcohol (Sohn and Kornicker, 1969, p. 100).

We produced nodules during the present study in sun-dried *V. hilgendorfii* immersed for about 24 hours in about 10% buffered formalin. Because buffered formalin is the usual initial preservative of marine collections, especially plankton, nodules present in myodocopids preserved in this manner may not have been formed *in vivo*.

We had previously classified and illustrated nodules produced in the laboratory as spherical, hemispherical, discoidal, and anastomosing (Sohn and Kornicker, 1969, p. 100, 101, Pl. 1). The

PLATE 4—Figs. 1, 2. *Vargula hilgendorfii* (Müller, 1890). Cut cross-section of left valve of carapace preserved in alcohol showing net-like counterpart of coarse granular component. USNM 93001A. Locality 11.1, shows epicuticle, frame of coarse granular component and laminate component, approx. ×420. 2, detail of frame of coarse granular component, approx. ×2,100. Figs. 3–6. *Eusarsiella disparalis* (Darby, 1965). Cross-section of left valve showing epicuticle and endocuticle. USNM 152311. Locality 10. 3, 4, cross-sections, epicuticle (arrow on fig. 5), fine granular, coarse granular, and laminate components, approx. ×930. 4 is 90° to section on fig. 3. 5, 6, details of outer and inner parts, respectively, of cross-section on fig. 3, approx. ×3,400. Fig. 7. *Thaumatoconcha caraionae* Kornicker and Sohn, 1976. Broken cross-section of left valve, adult male, showing epicuticle and columnar component of endocuticle, approx. ×890. USNM 143855B. Locality 12. Figs. 8–10. *Thaumatoconcha tuberculata* Kornicker and Sohn, 1976. Broken fragment of adult male. USNM 143796MZZ. Locality 13. 8, oblique view showing cross-section of epicuticle and columnar component, and inner surface of fragment, approx. ×180. Outer edge towards bottom of plate. 9, 10, detail of fig. 8 showing epicuticle, fine granular and columnar components of endocuticle, approx. ×870 and ×4,900, respectively; area of 10 shown on fig. 9 by arrow.
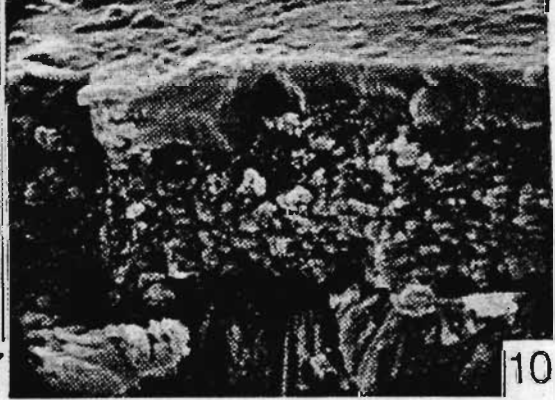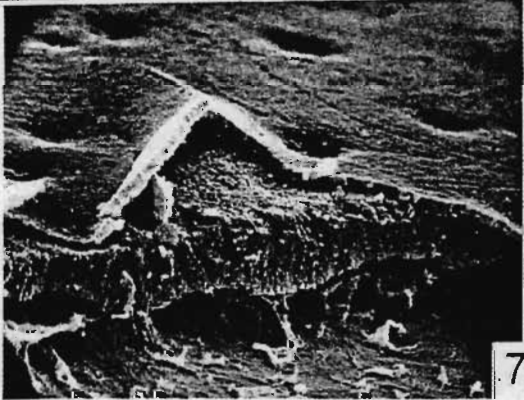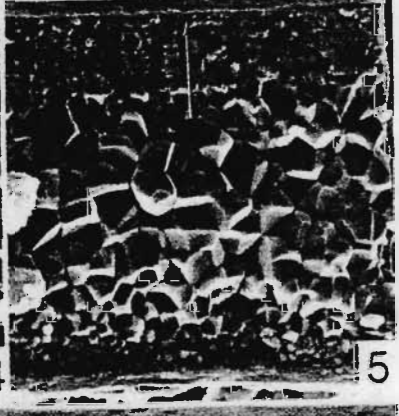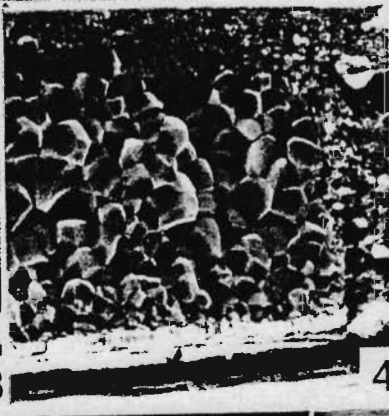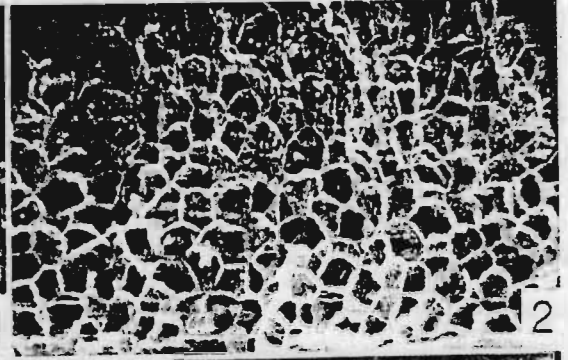
ultrastrucrures of some of these forms are illustrated herein with SEM micrographs (Pl. 5, figs. 1–6; Pl. 6, figs. 1–8).

Discoidal and hemispherical nodules in a fragment of *V. hilgendorfii* illustrated on Pl. 3, fig. 6, and on Pl. 6, fig. 9, are postulated to have formed *in vivo* because this specimen was preserved in alcohol immediately after collection. Coalescing nodules in *Thaumatoconcha tuberculata* are shown on Pl. 4, figs. 8 and 9. Acicular nodules are shown replacing the coarse granular component in *Eusarsiella texana* (Pl. 5, figs. 7, 9). We assume that the concentric spheres in *Spinacopia* sp. are nodules (Pl. 5, figs. 10–13), but their method of formation is enigmatic.

Ultrastructures of shells at margins: The ultrastructure of the shell at the margins of *Vargula hilgendorfii* (Pl. 3, figs. 1–5) differs from the rest of the shell. The laminate layer at the margins replaces the coarse granular layer and forms the infold (Pl. 3, figs. 2–5). Pl. 3, figs. 3 and 4 clearly demonstrate the nature of the infold. Laminae also replace the coarse granular component along the attached margin (Pl. 3, figs. 1, 2) where the valves are joined by the ligament shown by the arrow on Pl. 3, fig. 7.

Ultrastructures of juveniles: The ultrastructures of the valves of two juveniles of *V. hilgendorfii* were examined (Pl. 7). The smaller juvenile (greatest length 1400 μm) has an ultrastructure that is more or less similar to that of the adult, except that the grains of the coarse granular component are less well defined (Pl. 7, figs. 1, 2). The larger juvenile (greatest length 1700 μm) has a homogeneous component similar to that of the adults. There are fewer grains in the coarse granular component (Pl. 7, figs. 3, 4), and the grains are relatively larger than in the adults. As in the adults, the coarse granules are convex upward and decrease in size towards the inside of the valve.

TAXONOMIC DISTRIBUTION OF COMPONENTS

This and prior studies of the ultrastructures in the mainly pelagic suborder Halocypridina indicate that taxa in the superfamily Halocypridacea have laminate endocuticles, and the mainly benthonic Thaumatocypridacea have columnar, or columnar and fine granular, endocuticle. The endocuticle in the suborder Cladocopina is fine granular and columnar. The endocuticle in the Myodocopina has a combination of one to four components.

PLATE 5—Figs. 1–6. *Vargula hilgendorfii* (Müller, 1890). Discoidal and anastomosing crystalline nodules prepared in the laboratory. USNM 193163B.   Locality 7. 1, 2, discoidal nodule, approx. ×180 and detail of lower front, approx. ×900. 3–6, anastomosing nodule. 3, 4, detail of top surface near right side of fig. 3, approx. ×180 and ×900, respectively. 5, edge view of unbroken surface at right side of fig. 3, approx. ×2,250. 6, edge view of broken surface on bottom of fig. 3 showing dense ultrastructure, approx. ×890. Figs. 7–9. *Eusarsiella texana* (Kornicker and Wise, 1962). Cut sections showing coarse granular and laminate components, and nodules replacing coarse granular component. USNM 144004. Locality 9. 7, edge of valve, approx. ×300. 8, detail of coarse granular component, approx. ×1,650. 9, detail of nodule shown by arrow on fig. 7, approx. ×5,400. Note similarity to nodule illustrated on Pl. 6, fig. 8. Figs. 10–13. *Spinacopia* sp. Left valve with many spherical nodules replacing coarse granular component. USNM 149315. Locality 2. 10, cut section showing two components: coarse granular component partly replaced by nodules above inner laminate component, approx. ×2,250; 11, detail of nodules, approx. ×2,250. 12, detail of polygonal outline of coarse granule shown by arrow on fig. 11, approx. ×6,700. 13, detail of spherical concretion inside large nodule, approx. ×1,350. Figs. 14, 15, *Eusarsiella disparalis* (Darby, 1965). Etched replica of polished cross-section of left valve, showing polygonal outlines surrounding the granules. Same specimen as Pl. 4, figs. 3–6. 14, approx. ×700; outer surface to top. 15, detail from fig. 14, approx. ×5,650; outer surface of valve to right.
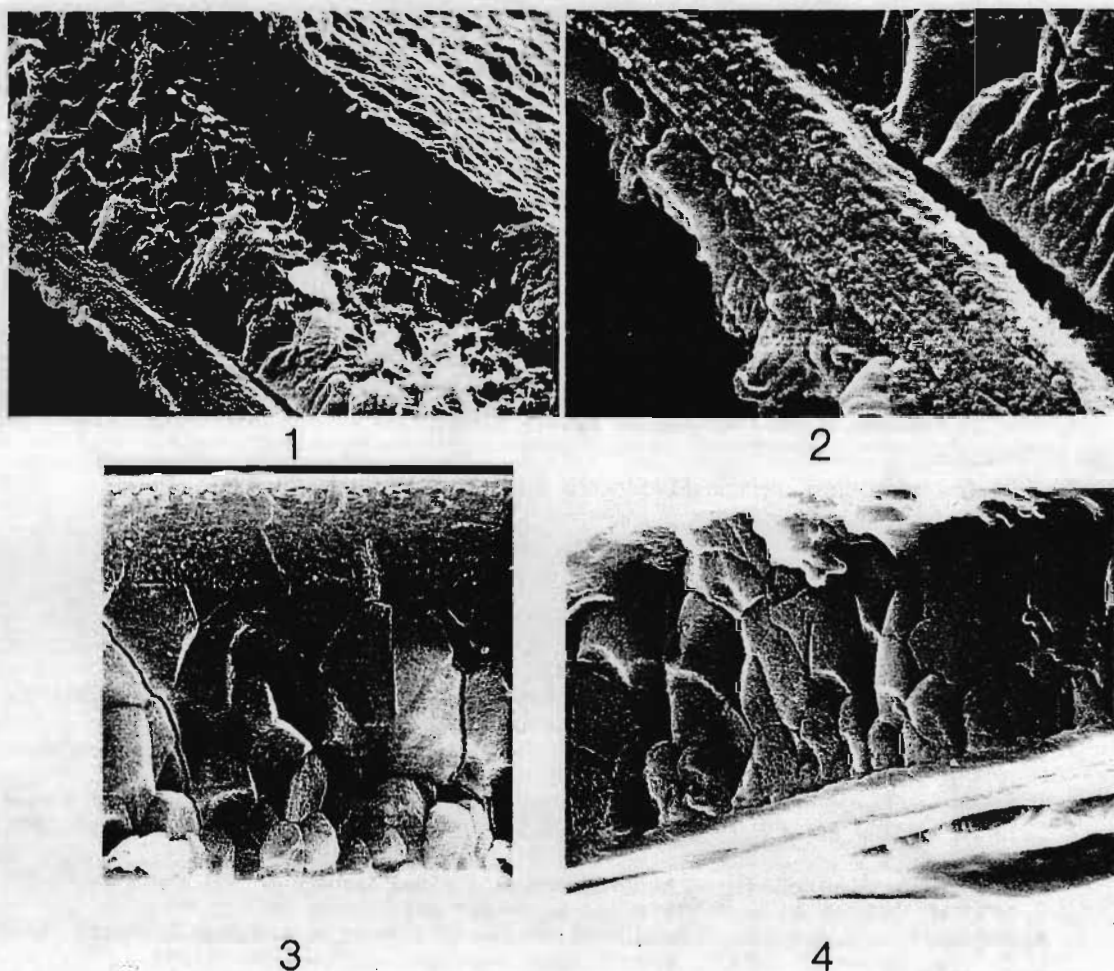
254
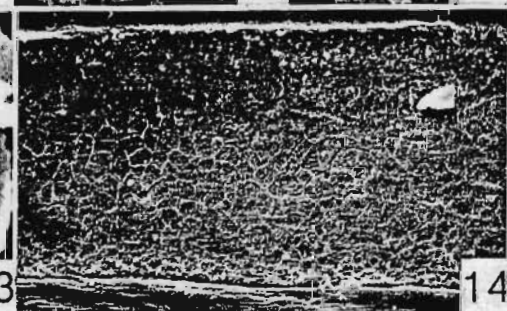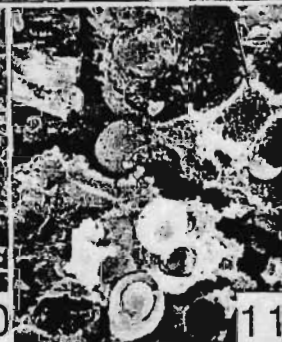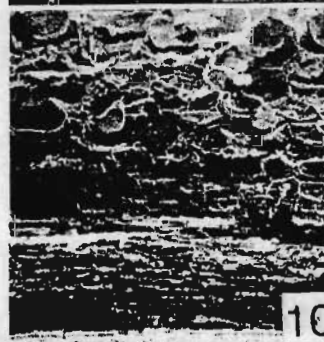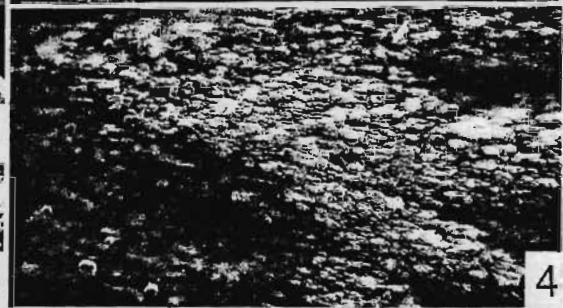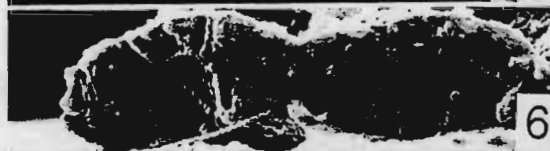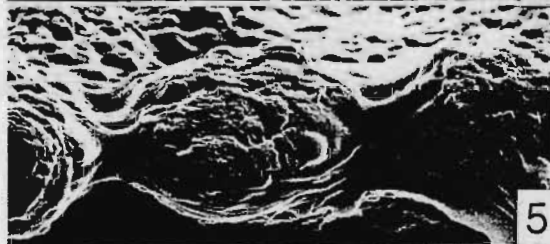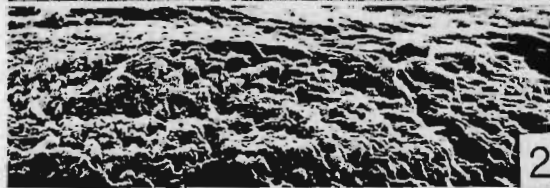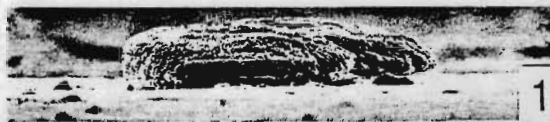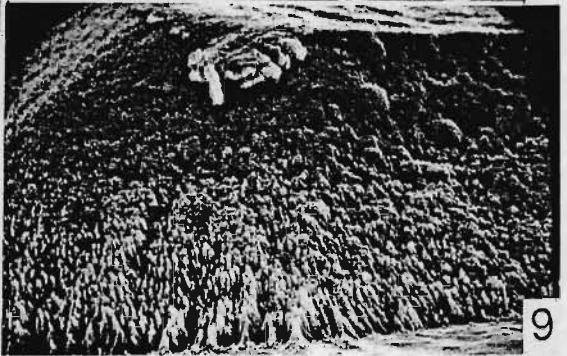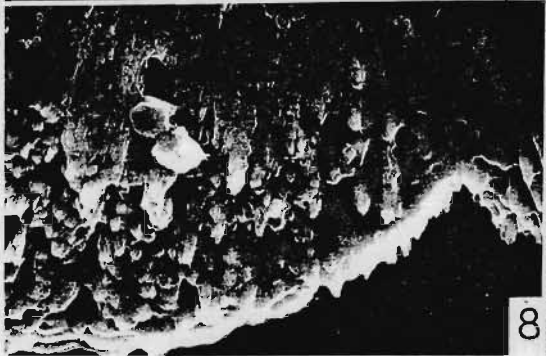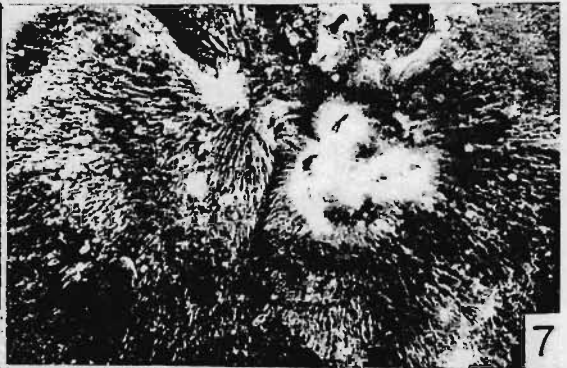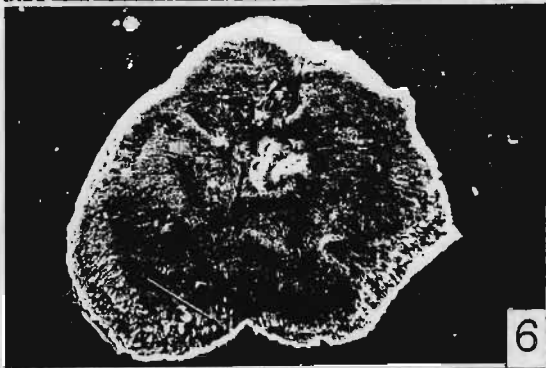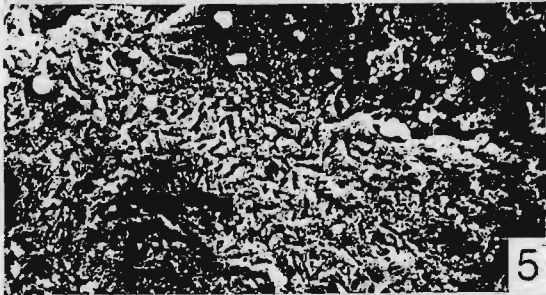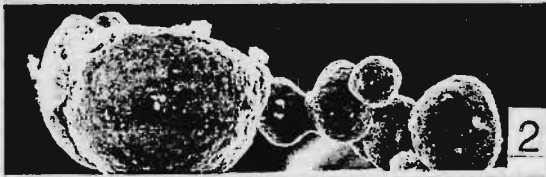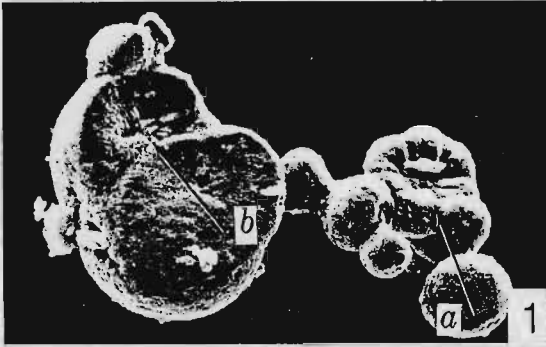
PLATE 7—Figs. 1–4. *Vargula hilgendorfii* (Müller, 1890). Broken sections of juvenile sun-dried carapaces. Locality 7. 1, section showing homogeneous, coarse granular and laminated endocuticle, approx. ×3,100. 2, detail of lower middle part of fig. 1, approx. ×8,900. USNM 193163D, greatest length 1.40 mm. 3, 4, sections showing epicuticle, and homogeneous and coarse granular components of endocuticle, approx. ×3,100. Components below coarse granular component missing. USNM 193163E, greatest length 1.70 mm.

PLATE 6—Figs. 1–8. *Vargula hilgendorfii* (Müller, 1890). Hemispherical, spherical and discoidal crystalline nodules produced in laboratory. USNM 193163B. Locality 7. 1, 2, top and end views of assemblage, approx. ×220. Note variation in size of spherical nodules. 3, detail of inner surface of hemispherical nodule shown by arrow *a* on fig. 1, approx. ×890. 4, detail of upper surface of hemispherical nodule shown by arrow *b* on fig. 1, approx. ×890. 5, detail of surface structure in area shown by arrow on fig. 4, approx. ×890. Short black lines represent spaces between adjacent crystals. 6–8, discoidal nodule, detail of upper surface, and detail of lower edge shown by arrow on fig. 6, approx. ×180, ×450, and ×890, respectively. Fig. 9. *V. hilgendorfii*, detail of upper part of nodule showing acicular structure, approx. ×3,050. USNM 193164. Locality 8. Same valve illustrated on Pl. 3, fig. 6. Top of nodule towards inner surface of valve.

CONCLUSIONS

Although the ultrastructures of only a few of the known myodocopid species have been examined, our data suggest the following:

1. The pelagic Halocypridacea (*Conchoecia, Halocypris*) have laminate endocuticles.

2. Species in the pelagic genera *Gigantocypris* and *Macrocypridina* (Cypridinidae) have laminate endocuticles.

3. Members of the pelagic genus *Codonocera* (Cypridinidae) have laminate and coarse granular endocuticles.

4. Members of the benthonic Cladocopa have columnar and fine granular endocuticles.

5. Benthic Thaumatocypridacea have columnar, or columnar and fine granular, endocuticles.

6. Benthic members of the Cypridinacea have a combination of one to four components in the endocuticles.

7. With few exceptions, pelagic Myodocopa have laminate endocuticles.

LIST OF COLLECTION LOCALITIES

1. *Gigantocypris muelleri* collected SW of the Kerguelen Islands, depth 3240 m, April 12, 1974, Sanders dredge (see Kornicker, 1976, p. 47).

2. *Conchoecia atlantica, Spinacopia* sp. collected off West Africa, R. V. *Atlantis II*, cruise 42, May 23, 1968, station 202, 8° 48′S, 12° 52′E, depth 527–541 m (new record).

3. *Asteropterygion setiferum* collected off Ivory Coast, 5° 12′N, 4° 09′W, depth 40 m (see Kornicker, 1975, p. 2).

4. *Macrocypridina castanea* collected near Bermuda, R. V. *Trident*, cruise 1, June 2, 1970, station 10–5B, 32° 33′N, 64° 04′W, depth 600 m, discrete depth sampler (see Kornicker and others, 1976, p. 3).

5. *Scleroconcha folinii* collected off Mauritania, R. V. *Thalassa*, January 29, 1971, station X048, 28° 50′05″N, 17° 39′00″W, depth 270 m, (see Kornicker and Caraion, 1977, p. 40).

6. *Polycope* sp. collected in South Atlantic, Walvis Bay, off Ruanda, R. V. *Atlantis II*, cruise 42, May 23, 1968, station 201, 09° 25′S, 11° 35′E, depth 1964–2031 m, trawl (new record).

7. *Vargula hilgendorfii* collected and immediately sun-dried by Dr. Y. Haneda, September 1954, at Zushi Beach, Kanagawa, Japan (see Sohn and Kornicker, 1969, p. 100).

8. *Vargula hilgendorfii* same locality as 7, but preserved in alcohol instead of sun-dried.

9. *Eusarsiella texana* collected off Bird Key, Charlotte Harbor, Florida, July 1971, depth 1–3 m, Ockelman dredge (see Kornicker, 1986, p. 7).

10. *Eusarsiella disparalis* collected off Bird Key, Charlotte Harbor, Florida May 1, 1974, depth 2–3 m, Ockelman dredge (see Kornicker, 1986, p. 8).

11. *Vargula hilgendorfii* collected by Dr. D. J. Pletsch, U.S. Public Health Service, at Chiba-Ken, Japan, Sept. 1948 (new record).

12. *Thaumatoconcha caraionae* collected in South Atlantic, R. V. *Atlantis II*, cruise 60, March 14, 1969, station 245A, 36° 55′42″S, 53° 01′24″W, depth 2707 m, large epibenthic sled (see Kornicker and Sohn, 1976, p. 21).

13. *T. tuberculata* collected in South Atlantic, R. V. *Atlantis II*, cruise 31, February 12, 1967, station 169A, 8° 03′00″S, 34° 23′00″W to 8° 02′00″S, 34° 25′00″W, depth 587 m, epibenthic sled (see Kornicker and Sohn, 1976, p. 21).

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DISCUSSION

De Deckker: I wish to inform you that nodules similar to those which you talked about have been found in "planktonic" free swimming ostracods in Australia. These ostracods belong to the large (more than 3 mm) genera *Australocypris* and *Mytilocypris*. I am convinced that these nodules are forming within the ostracods after death and after the ostracods became dehydrated after having been preserved in alcohol. This could therefore result from the effect of dehydration of a substance containing some Ca and CO_3 molecules.

Sohn: Thank you for the new information, because in our paper we state that nodules have not been reported in ostracods other than myodocopids. In our experiments we observed that alcohol (70% ethanol) was one of the few liquids that did not produce nodules.

De Deckker: Knowing that monohydrocalcite is an unstable mineral, it is therefore unlikely that one will find these nodules in the fossil record.

Sohn: Sohn and Kornicker (1969, p.102) suggested that structures described in the Lower Carboniferous *Cypridinella superciliosa* Jones, Kirkby and Brady, 1874, may be discoidal nodules, and on p. 106 we suggested that myodocopid nodules may contribute carbonate particles to marine sediments.

Siveter: Do you consider that the nodules you have described are synonomous structures to the calcareous discs and spherulites which Bate and Sheppard (Fossil and Recent Ostracods, British Micropal. Soc. 1982. Eds. Bate *et al.*) described from Recent myodocopids?

Sohn: It has been established that large calcite nodules or discs may form in myodocopid shells at two different times: 1, while the animal is alive; and 2, after it has died. Bate and Sheppard (1982) and Smith and Bate (1983, *Jour. Micropalaeontology*, 2: 105–110) interpreted the nodules in living myodocopids to be a step in the normal calcification of the shell. We think that nodules in living myodocopids are atypical and not the usual way in which myodocopids calcify. A study of myodocopids *in vivo* is necessary to resolve this problem.

Keyser: Do you look at the same places on the ostracod shell? I found, for instance, different crystallization on places where the muscles adhere.

Sohn: We have insufficient data to draw conclusions concerning the ultrastructure in the vicinity of the central adductor muscles. There are ultrastructure changes near the hinge and free margin (Pl. 3).